Human Exploration and Operations (HEO) Systems Engineering and Integration (SE&I) Decision Memorandum

Planning Guidance for Artemis Mission Durations as Testbeds to Reduce Risks for Human Missions to Mars

HEO-DM-1004

Decision:

The purpose of this memorandum is to establish mission durations to be used for Artemis Reference Missions (RMs)[1] to support preparation and risk reduction for human Missions to Mars.

Background:

Artemis missions to return humans to deep space and lunar surface environments will provide new opportunities for cross-platform human research to reduce risk for future Mars missions. Crewed missions to Mars will expose crews to combined spaceflight hazards including Altered Gravity, Isolation and Confinement, Distance from Earth, Hostile/Closed Environment, and Space Radiation. Currently, these hazards pose risks to human health and performance during proposed Mars missions, and mitigation techniques are still under development. The Human Research Program (HRP) performs research on the ground, the International Space Station (ISS) and Artemis to develop and test risk mitigations. Extended duration Artemis missions offer higher-fidelity representative of Mars missions to validate risk mitigation strategies.

Summary:

For the purpose of planning and analysis, the appended tables provide HRP's crewed mission recommendations for Mars-relevant human risk mitigation research with rationale. The basis for the durations is current Human Exploration Operations Mission Directorate (HEOMD) Mars planning (HEO-DM-1002 "Mars Mission Duration Guidance for Human Risk Assessment and Research Planning Purposes"), Artemis Near Rectilinear Halo Orbit (NRHO) constraints, and HRP's current evidence for duration-dependent human adaptation to the space environment due to spaceflight hazard stressors.

Three potential extended RMs of increasing duration have been identified to be of research value: 1) Research and Development Testbed (based on durations in PPBE22 Manifest), 2) Applied Risk-Reduction Testbed (a longer set of missions), and 3) Risk-Reduction Integrated System Validation (equivalent to Mars mission durations). Key to each research risk reduction recommendation is extended stays in the microgravity deep-space environment to allow for crew adaptation prior to descent and transition to the partial-gravity lunar surface environment, corresponding to the transit, landing, and surface phases of future Mars missions. Additionally, extended Artemis should employ a progressively Earth-independent crew health and performance system integrated with the habitats for system validation. The initial, shorter RMs will inform and support later extended missions that will build up to the Risk-Reduction Integrated System Validation RM.

Use of these potential Artemis RMs for the assessment is underpinned by rich terrestrial and Low Earth Orbit (LEO) spaceflight experience, and the knowledge base will continue to evolve as human spaceflight and research progress. ISS has and will continue to serve as a transit

[1] Reference Mission: An illustrative example of a mission (graphical and text) exploring potential concepts during pre-formulation architectural trades; one of many different mission options that are studied to assess potential future program/projects (XM-M1842020, "Artemis Definitions of Mission Terms," August 5, 2020.)

analog in LEO, and the upcoming ISS Complement of Integrated Protocols for Human Exploration Research (CIPHER), with six-month and one-year studies, will provide additional needed long-duration data. The recommended Artemis durations correspond to the ISS CIPHER study to allow for comparative analysis and validation. While past and future ISS data will provide a solid foundation, knowledge and systems will evolve as planners define Artemis missions and crews experience the deep-space hazard environment for longer durations with increasing independence from Earth.

HEO Forward Plan:

SE&I will convene a special technical interchange meeting (TIM) in February 2021 to address these reference architectures and trades to determine planning durations for extended Artemis missions (beyond 105 days in microgravity prior to landing and at least 30 days on the surface in the 2030s). Given that crew adaptation to the habitable environment over extended Artemis durations and research objectives may drive additional Artemis Crew Health and Performance requirements, SE&I is requesting input on the questions below from the identified stakeholders to make an integrated assessment to meet expected procurement schedules:

- ***What are the interactions between human systems and the architecture for extended duration missions?***
    - Strategy and Architectures team:
        - What are the impacts to the Exploration Campaign to support the missions defined in the appended tables?
        - Could the transportation architecture support the Risk-Reduction Integrated System Validation Reference Mission?
        - Could cumulative testing over the shorter reference missions decrease the duration required (less than the 365+30+270 days proposed) for the Risk-Reduction Integrated System Validation mission, thus easing the burden on campaign logistics and refurbishment to recover prior to targeted Mars mission opportunities?
    - Health and Medical Technical Authority (HMTA):
        - Definition of system impacts/requirements to be levied specific to mitigating risk associated with surface landing loads (HLS).
        - Definition of dwell or acclimation times and activities associated with post-surface landing readiness for EVA operations.
        - Would the HMTA require any crew countermeasures or health and performance assessments while in the HLS prior to the first EVA that could impact the HLS design or capabilities?
        - What would be the required Level of Care and Crew Health and Performance System capabilities for each duration as described herein?
        - At these durations, is the expectation that crew performance decrements could require automated HLS landing?
    - Human Research Program (HRP):
        - In the context of the Artemis testbed missions with 30-60 days on the lunar surface and with HMTA, what are the options for medical

equipment on the surface or in lunar orbit that are synergistic with providing contingency medical care and research data?
- Do the HRP research objectives require unique operations or capabilities which would drive the Foundation Surface Habitat configuration?
- Do the HRP research objectives require unique operations or capabilities in HLS post-landing

- ***Given that the current NRHO mission plans include 11-14 days between departing the lunar surface and return to Earth (6-7 days from lunar surface and stay time in NRHO and 5-6 days from Orion NRHO departure to Earth), what is the trade space of return time vs. measurement equipment in cislunar or on the lunar surface to achieve research objectives on these missions (based on best knowledge available today)?***
  - Human Research Program (HRP)*:*
    - What information about the human system is lost depending on the time between lunar ascent and Earth return?
    - What measurement capabilities on the lunar surface or in lunar orbit could mitigate the loss of information?
    - What risks for Mars missions cannot be suitably addressed without data collected on the partial gravity state of these human systems?
    - What would be the value of longer durations in microgravity beyond the lunar surface to understand re-adaptations to microgravity after the lunar surface?
  - Health and Medical Technical Authority (HMTA):
    - Does the 11–14-day evacuation time from the lunar surface to Earth via NRHO drive a change in medical level-of-care requirements on the lunar surface or in lunar orbit?

HEO SE&I will use the results of the TIM to evaluate additional impacts to the strategic planning of extended Artemis missions that would occur in the 2030s. SE&I will use these results to generate mission ground rules and assumptions and determine requirements for sustained lunar architectures and acquisitions. Points of contact for responses to this memo are Julie Robinson (SE&I Science & Utilization Acting Manager), Douglas Craig (SE&I Strategy and Architecture Acting Manager), Neal Zapp (NASA HMTA Manager), and Michael Waid (HRP Artemis Integration lead).

Approval:

Deputy Associate Administrator,
HEO Systems Engineering & Integration

Marshall Smith

Appendix A: Planning Guidance for Extended Artemis Testbed Mission Durations

RESEARCH AND DEVELOPMENT TESTBED RM (PPBE22 Manifest)		
Mission Segment:	**HRP recommendation:**	**Rationale:**
Time in Microgravity Pre-Lunar Surface	45-105 days, 75 days minimum preferred.	45 days is the minimum time for the human to adapt to the environment. Previous spaceflight data indicates that in 75 days Spaceflight-associated Neuro-ocular Syndrome (SANS) will manifest in 80% of susceptible people.
Time on Lunar Surface	30-60 days	30 days minimum corresponds to the minimum duration for Mars RM surface ops. Due to the small differential between lunar gravity (1/6g) and microgravity, 60 days might be needed to detect a signal.
Time to Return to Earth Post-Lunar Surface	Rapid return preferred[2]. 11 -14 days planned architecture.	Rapid return allows greater evaluation of 1/6 g role in adaptations and data collection techniques not available in space. The signal on partial-gravity state degrades the longer the crew stays in microgravity. The planned return times from the lunar surface assume Artemis NRHO based architecture physics.
Total Crew Sample Size (N)	N = 4-10 subjects	This allows for meaningful outcomes of data. Four crew is the absolute minimum to see effects that can extrapolated out to a larger population. Ten crew is the minimum sample size for good statistics. HRP recommends proceeding to longer missions as soon as possible.

[2] This preference is driven by the need for observations of crew adaptation to partial gravity that cannot be made on the lunar surface and depend on Earth facilities for measurement. Due to the constraints of the NRHO architecture of 11–14-day return times, HRP will assess the research impacts as part of the HEO forward plan.

APPLIED RISK-REDUCTION TESTBED RM		
Mission Segment:	**HRP recommendation:**	**Rationale:**
Time in Microgravity Pre-Lunar Surface	120-180 days	120–180-day durations in *cis*-lunar orbit prior to lunar surface visits allows for comparison to ISS as a transit analog data. 120 days is the minimum to understand subsequent partial gravity exposure. Space radiation exposure becomes more of a relevant stressor for 120–180-day durations.
Time on Lunar Surface	30-60 days	30 days minimum corresponds to the minimum duration for Mars RM surface ops. Due to the small differential between lunar gravity (1/6 g) and microgravity, 60 days might be needed to detect a signal.
Time to Return to Earth Post-Lunar Surface	Rapid return preferred. 11-14 days planned architecture.	Rapid return allows greater evaluation of 1/6 g role in adaptations and data collection techniques not available in space. The signal on partial-gravity state degrades the longer crew stays in microgravity. The planned return times from the lunar surface assume Artemis NRHO based architecture physics.
Total Crew Sample Size (N)	N = 10-12 subjects	Allows meaningful outcomes of data. Ten crew is the minimum sample size to produce results that can be applied across a population.

RISK-REDUCTION INTEGRATED SYSTEM VALIDATION RM		
Mission Segment:	**HRP recommendation:**	**Rationale:**
Time in Microgravity Pre-Lunar Surface	360 days	360 days corresponds to the Mars RM transit duration, and data collected will be comparable to that from one-year ISS missions.
Time on Lunar Surface	30-60 days (TBR)	30 days minimum corresponds to the minimum duration for Mars RM surface ops. Due to the small differential between lunar gravity (1/6 g) and microgravity, 60 days might be needed to detect a signal. This duration is to be resolved (TBR), and preceding Extended Artemis Testbed missions will inform it.
Time in Microgravity post-lunar surface	270 days	A minimum of 270 days is believed to model the expected Mars RM return duration on the order of one-year. This assumes extensive in-situ analysis capability and medical level of care V like needed for the eventual Mars mission. In-situ analysis capability is needed to understand the crew baseline physiological state before adapting back to microgravity during the return transit to Earth and the course of change. Additionally, the overall Risk-Reduction Integrated System Validation RM mission duration would be longer than any previous spaceflight mission. Surveilling for long-term health consequence prevention would be required, and the crew would have the opportunity to evacuate if needed.
Total Crew Sample Size (N)	N = 10-12 subjects. N = 4 may be acceptable with Applied Risk-Reduction Testbed	Ten crew is the minimum sample size to produce results that can be applied across a population. Due to agency needs and constraints, this mission may only occur once. Four crew is the absolute minimum to determine meaningful outcomes of data, if HRP is able to leverage data from all other missions and observations, including from the Applied Risk-Reduction Testbed RM, as best as HRP can see today.